ARL-MAT-TM-403 AR-006-113

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

Aircraft Materials Technical Memorandum 403

EXAMINATION OF THE MICROSTRUCTURE OF 7050 ALUMINIUM ALLOY SAMPLES

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Approved for public release

AUGUST 1990

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SUMMARY

Aluminium Alloy 7050 is used extensively in the F/A-18 aircraft. This report describes the results of examination of a number of samples of Aluminium Alloy 7050 which were taken from FS 488 bulkhead fatigue test specimens adjacent to the fatigue failures and from thinner material which has been used for fatigue test coupons by ARL and F/A-18 manufacturers.

DSTO ARL MELBOURNE

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INTRODUCTION

As part of the evaluation of the structural life of the F/A-18 fighter aircraft, samples of the Aluminium Alloy 7050 taken from several different fatigue specimens, including F/A-18 FS 488 Bulkhead fatigue test articles, several laboratory fatigue test specimens, and elsewhere, were examined metallurgically. The microstructure of the bulkhead material was also examined using thin foils in a Transmission Electron Microscope. These examinations revealed marked variations in the grain size, orientation and morphology, which were found to depend to some extent on the thickness of the original rolled plate material, and may have a marked effect on the initiation of fatigue in F/A-18 major structural components.

The period of fatigue which is of particular concern involves crack-initiation and early crack growth. This paper compares samples taken from areas adjacent to the fatigue failures in F/A-18 FS 488 Bulkhead fatigue tests FT40, FT41 and FT40R which were carried out by the manufacturers, and the 488 Bulkhead fatigue tested in Aircraft Structures Division ARL, with samples taken from fatigue coupon tests from the vertical tail element program carried out by the manufacturers, ARL Structures Division and ARL Aircraft Materials Division.

Alloy 7050

Alloy 7050 is a zinc-magnesium-copper type aluminium alloy which was developed by Alcoa for the US Navy and Air Force to provide a high-strength material resistant to stress-corrosion, primarily for thick-section applications. In addition to its high stress-corrosion resistance, it can be heat-treated and mechanically worked to give a higher toughness at a given strength level than most other 7XXX series aluminium alloys.

The nominal composition, and the composition limits of 7050 are shown in Table 1:

Table 1
7050 Nominal Composition %

Zn	Cu	Mg	Zr
6.2	2.3	2.25	0.12

Composition limits %

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
0.12 max	0.15 max	2.0-2.6	0.10	1.9-2.6	0.04	5.7-6.7	0.06 max	0.08-0.15

Others (Each) 0.05; Others (total) 0.15; Balance Aluminium.

Alloy 7050 is unusual in two respects: it contains zirconium (in place of chromium) to control recrystallization and grain size, and it has a Cu/Mg ratio greater than 0.8. The absence of chromium contributes to the low quench-sensitivity of 7050, and the relatively high copper content results in additional strengthening during second-step ageing [1].

Thermal and Mechanical Processing

The solidification and subsequent thermo-mechanical treatments of alloy 7050 are similar to those of alloy 7075. Ingots exceeding 13500 kg have been cast with a typical microstructure consisting of αAlFeSi script-like (sometimes blocky) structures, blocky Mg_2Si and a lamellar eutectic consisting of $Al+Al_2CuMg+MgZn_2$, which all occur at the interdendritic grain boundaries.

A fine precipitate of $MgZn_2$ is usually visible in the aluminium phase and results from slow cooling after solidification. Very slow cooling may result in needles of $MgZn_2$ forming a Widmanstatten pattern. The $MgZn_2$ phase is highly soluble and will readily go into solution during homogenization. Blades of Al_7Cu_2Fe have been known to form directly on solidification when the solidification rate is slow.

The volume of liquid is approximately 6% [2] greater than the solidified aluminium. Isolated pools of liquid metal which may form during solidification will result in shrinkage porosity. High stresses are also produced during solidification of alloy 7050, and can result in further shrinkage porosity. This usually occurs at the interdendritic grain boundaries, particularly triple points. Such pores are typically large and angular.

Gas porosity, principally that caused by hydrogen coming out of solution during solidification, can be difficult, if not impossible, to distinguish from shrinkage porosity. Small amounts of hydrogen present in the aluminium melt tend to form nearly spherical pores on alloy solidification, while large amounts of hydrogen produce pores which are more angular and have the same shape as shrinkage pores.

The solidification structure usually produces a measure of dendritic coring. The formation of primary phases such as $ZrAl_3$ may occur at temperatures above the solidus of aluminium. Large primaries as inclusions can be detrimental to the mechanical properties of wrought products, i.e. inclusions with a diameter of 0.13mm (0.005 inch) have been found to decrease the fracture toughness by as much as 50% [2].

Since cast ingots of alloy 7050 develop high internal stresses during cooling, cracking may result when they are cooled to room temperature. Because of the cracking problems, ingots are usually transferred immediately to a stress-relief furnace and held for at least two hours (depending on the ingot size) at a temperature between 316°C and 454°C (600°F and 850°F). The precipitate structure following stress-relief will have transformed from αAlFeSi and the $Al+Al_2CuMg+MgZn_2$ eutectic to blocky Al_7Cu_2Fe and Al_2CuMg precipitates respectively with some of the $MgZn_2$ entering solid solution (depending on the temperature used) and the remainder forming blocky precipitates.

Homogenization is carried out prior to forming and reduces coring of the structure and dissolves most of the soluble constituents. Ingots of alloy 7050 are typically homogenized at 475°C (890°F) for 16 hours, followed by air cooling to room temperature. Homogenizing at 475°C starts the transformation of αAlFeSi to Al_7Cu_2Fe and dissolves the $MgZn_2$. Large ingots may take 4 to 5 days to cool to room temperature, but generally are not allowed to cool as rolling is performed at temperatures above 400°C (750°F).

Mechanical working of the ingot should cause the Mg_2Si, Al_7Cu_2Fe and any untransformed αAlFeSi to break up and become evenly distributed throughout the matrix.

Solution heat-treatment of alloy 7050 at 475°C (890°F) dissolves the soluble phases into solid solution and continues phase transformations not completed during homogenizing (preheating). Quenching and subsequent ageing depend on the required temper and are designed to produce alloy hardening by submicroscopic precipitation. Typically, for plate with a temper of T73651, a first ageing treatment is carried out at 107°C (225°F) followed by a second ageing at 177°C (350°F) [3].

MICROSTRUCTUAL EXAMINATION OF THE BULKHEAD MATERIAL

General Microstructure

The general microstructure of wrought alloy 7050 depends on the degree of working and type of heat-treatment. The samples examined in this memorandum were taken from plates with different thicknesses, and were in the T73 type heat-treatment condition. The typical T73 heat-treatment for 7050 plate involves a solution heat-treatment at 475°C, followed by quenching and a two-stage ageing treatment comprising of 6-8hr at 107°C followed by 24-30 hr at 163°C. Numbers listed after the T73 refer to working operations:- for example, TXX511 indicates that the material has been stress-relieved by stretching to produce a specified permanent set after solution heat treatment, followed by minor straightening. These mechanical treatments are incorporated primarily to relieve stresses induced during the quenching operation and involve a small controlled amount (1% to 3%) of plastic deformation [3].

Typically, the microstructure of 7050 in the T73 temper contains a submicroscopic precipitate of $MgZn_2$ dispersed throughout the matrix (which produces the age-hardening characteristics of the material), along with larger precipitates of Al_7Cu_2Fe, Mg_2Si, and Al_2CuMg. The grain structure, size and distribution of precipitates vary with the degree of mechanical work received. Ideally, the grains should be small and equiaxed, and the precipitates fine and evenly distributed. Micrographs (same plane) of thin forging (13mm approx.) and thick plate (150mm) in the as-polished condition (Figures 1 and 2) clearly show the large differences in the size and distribution of the visible precipitates for the two different plate thickness. Depending on the relative strength and ductility of the precipitates compared to the matrix, and the interfacial adhesion between the precipitates and the matrix, the shape of precipitates can be an important factor in the fatigue resistance of the material. It is generally considered that the precipitates are weak points in the material and that ideally they should exist as small rounded particles. This is the case with the thin plate material shown in Figure 1 but is clearly not the case represented in Figure 2, where the precipitates occur as blocky and elongated particles with some

Y-shaped particles which are typical of interdendritic grain boundary triple-point precipitates left after solidification and homogenization procedures. These Y-shaped artifacts are unusual in wrought aircraft-quality 7XXX series alloys. Further examination of the thick plate (150mm) in the as-polished condition revealed long thin precipitates more consistent with grain boundary films (Figure 3). These type of structures can cause significant degradation of fatigue resistance.

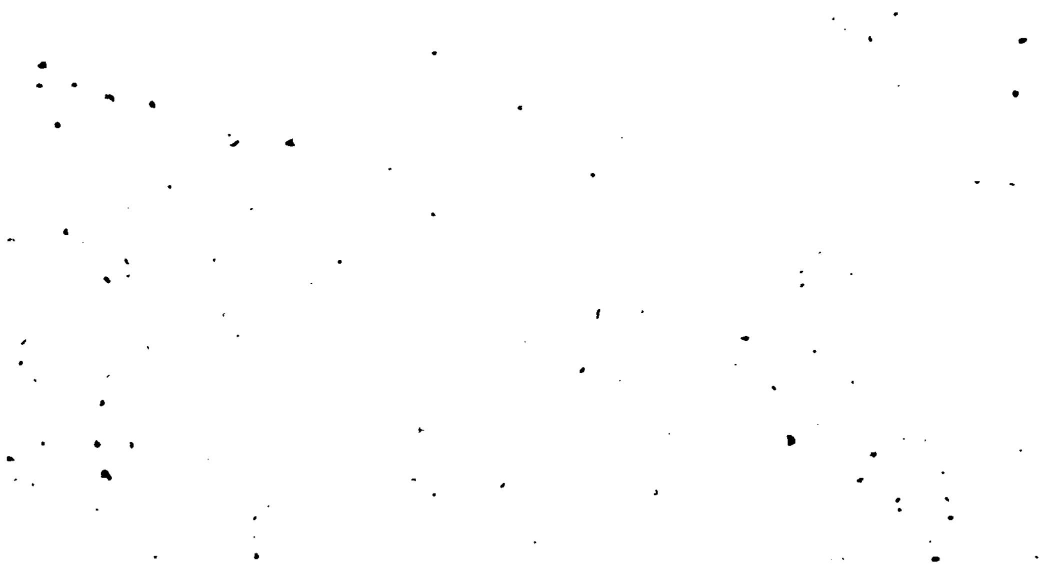


Figure 1 A micrograph of thin plate (13mm approx.) (specimen 1-7A) showing the distribution of precipitates. The light grey particles are Al_7Cu_2Fe and Al_2CuMg, and the black particles are Mg_2Si.

Magnification: 110 Unetched.

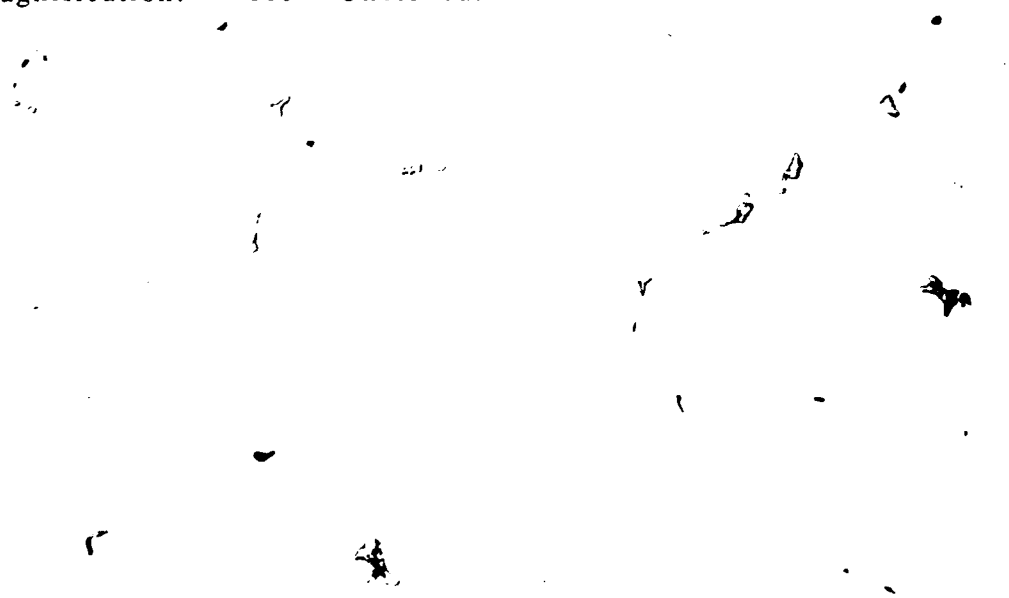


Figure 2. A micrograph of 150mm thick (six-inch) plate showing the distribution of precipitates.

Magnification: 110 Unetched

Figure 3. A micrograph of 150mm thick (six-inch) plate showing the distribution of precipitates and a film-like structure (arrow) remaining from the cast billet structure.

Magnification: 220 Unetched

Microstructures of samples examined

Thirteen samples of 7050 alloy were sectioned then examined by high power optical microphotography. These were from four sources:

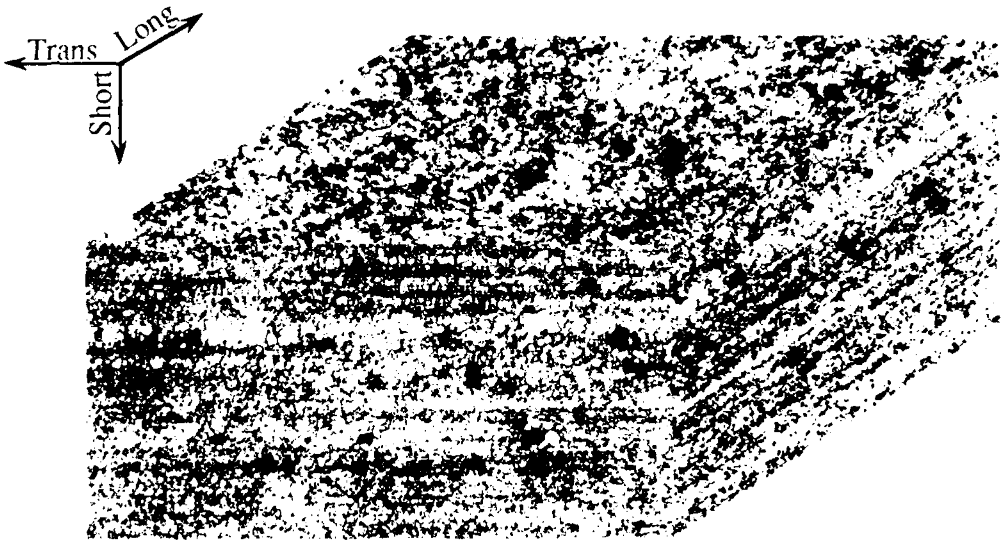
1. Material derived from 150mm (six-inch) plate material used in the manufacture of the F/A-18 FS488 bulkheads.
2. 6.35 mm (1/4-inch) plate material which has been used extensively at ARL for fatigue test specimens.
3. Material derived from fatigue test coupons used by the manufacturer in proving the vertical stabiliser cleat repair, and machined from forged material of approximately 13mm (1/2-inch) thickness.
4. 150mm (six-inch) plate material used by ARL for fatigue test specimens

More details about these samples are set out below in Table 2, followed by micrographs showing the three planes of each specimen produced by the rolling operation. Each of the specimens was etched in dilute Keller's reagent along with a separate etch in Molybdic acid. While all the samples are shown after etching in dilute Keller's reagent, only selected samples are shown after Molybdic acid etching, and then only where a significant difference was observed in details shown in the microstructure.

Table 2

Fig. No.	*Identification Marking*	*Original thickness*
4	Coupon specimen obtained from the manufacturer- 1-7A (Forged)	Forged, approx 13mm thick
5	Coupon specimen obtained from the manufacturer- A3-7 (Forged)	Forged, approx 13mm thick
6	Coupon specimen obtained from the manufacturer- 1-8A (Forged)	Forged, approx 13mm thick
7	Coupon specimen obtained from the manufacturer- A7-8 (Forged)	Forged, approx 13mm thick
8	ARL Aircraft Structures Division spec. KB-3	6.35 mm (1/4-inch) plate
9	ARL Aircraft Materials Division spec. JQC	6.35 mm (1/4-inch) plate
10	Porosity-containing FS488 bulkhead sample. Taken from between 50-75mm depth. Region of the original plate unknown.	150 mm (Six-inch) plate
11	F/A-18 FT40 in flange region of plate. Refer to Appendix Figure 1	150 mm (six-inch) plate
12	F/A-18 FT40 in centre region of plate. Refer to Appendix Figure 2	150 mm (six-inch) plate
13	F/A-18 FT41 in centre region of plate. Refer to Appendix Figure 3	150 mm (six-inch) plate
14	F/A-18 FT40R in flange region of plate. Refer to Appendix Figure 2	150 mm (six-inch) plate
15	F/A-18 488 Bulkhead fatigue tested in Aircraft Structures Division ARL. Refer to Appendix Figure 4	150 mm (six-inch) plate
16	150 mm (six-inch) plate acquired in late 1989 by Aircraft Structures Division ARL for fatigue test specimens. Taken from between 50-75mm depth.	150 mm (six-inch) plate

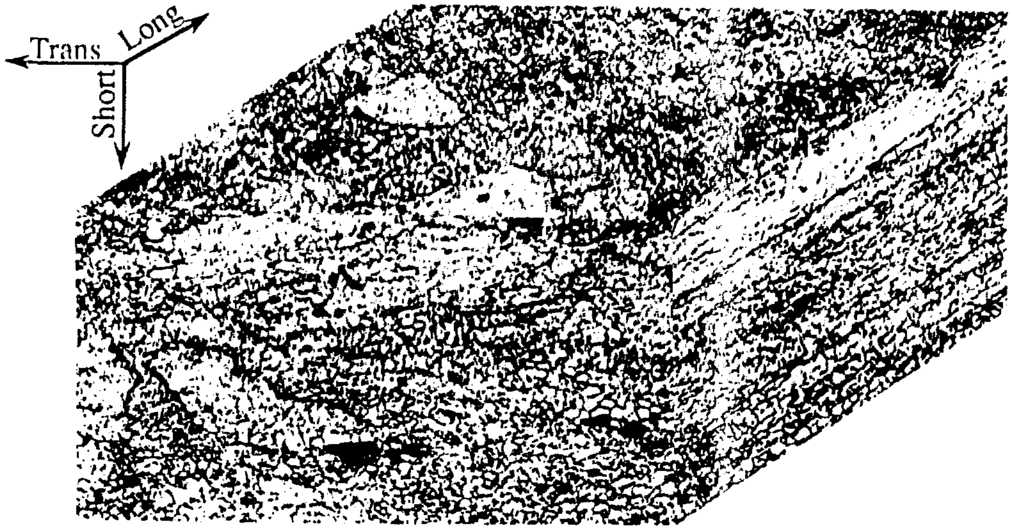
A



B

Figure 4. Manufacturer's coupon specimen 1-7A (approximately 13 mm thick) showing a fine grain structure (clearly indicated in B) with marked anisotropy (clearly indicated in A). Note the small size of the intermetallic precipitates, and their even distribution.

Magnification: 110 Etched: Dilute Keller's (4A), Molybdic Acid (4B).



A

B

Figure 5. Manufacturer's coupon specimen A3-7 (approximately 13 mm thick) showing a fine grain structure (clearly indicated in B) with a less marked anisotropy than the structures observed in the two previous Figures. This indicates that these specimens were machined from thicker plate. Note the small size of the intermetallic precipitates, and their even distribution.

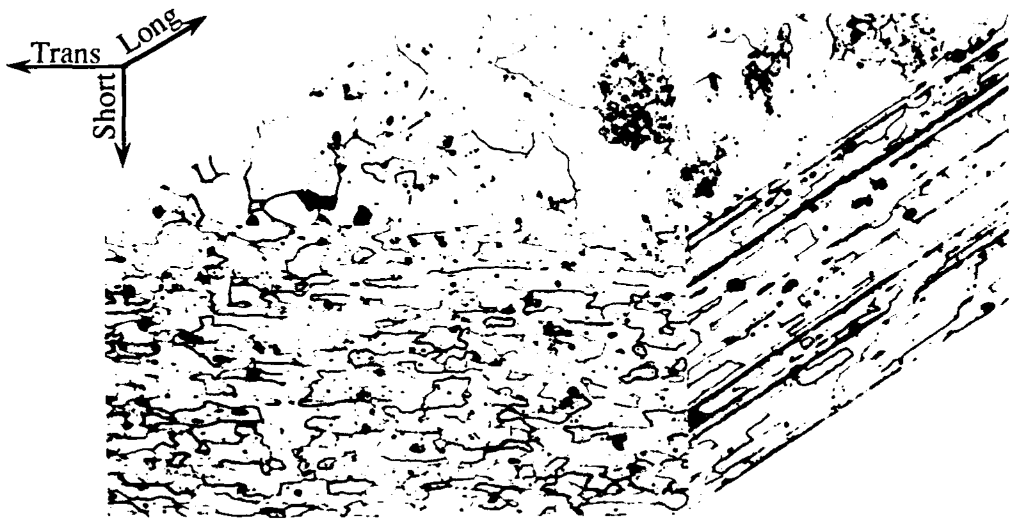
Magnification: 110 Etched: Dilute Keller's (6A), Molybdic Acid (6B).

Figure 6. Manufacturer's coupon specimen 1-8A (approximately 13 mm thick) showing features similar to those of Figure 4.

Magnification: 110 Etched: Dilute Keller's 4

Figure 7. Manufacturer's coupon specimen A7-8 (approximately 13 mm thick) showing features similar to those of Figure 5.

Magnification: 110 Etched: Dilute Keller's 4



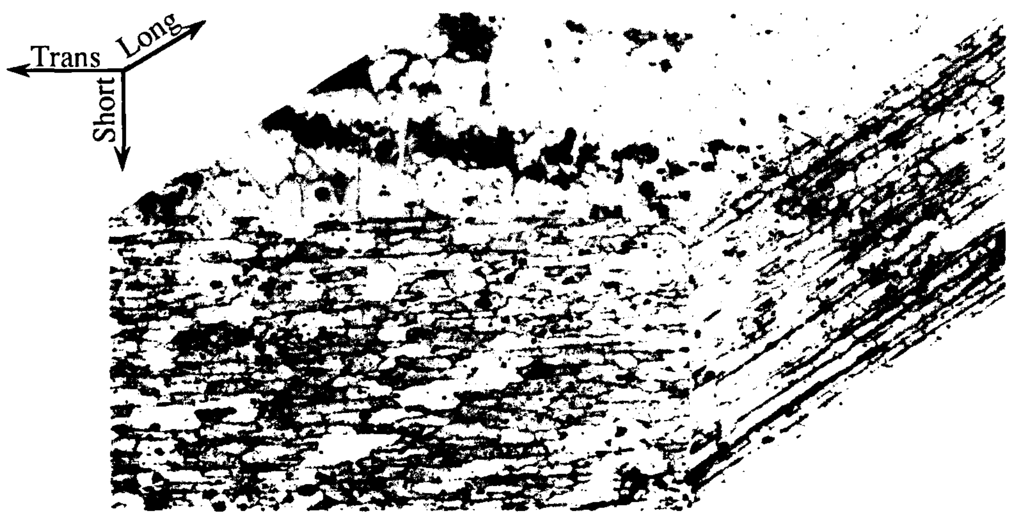
A

B

Figure 8. ARL Aircraft Structures Division specimen KB-3 machined from 6.35 mm (1/4-inch) thick plate. The structure has similar anisotropy to the specimens examined in Figures 4 and 5, although the size of the grains is greater. Small area of extremely fine grain structure can just be distinguished in B. Note the small size of the intermetallic precipitates, and their even distribution.

Magnification: 110 Etched: Dilute Keller's (8A), Molybdic Acid (8B).

A

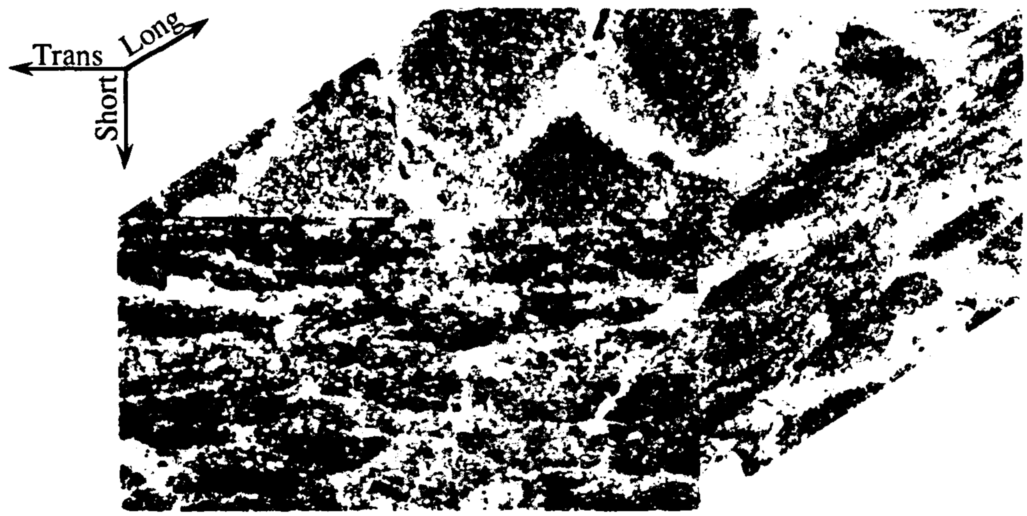


B

Figure 9. ARL Aircraft Materials Division specimen JQC machined from 6.35 mm (1/4-inch) thick plate. The structure is similar to the specimens examined in Figure 8. Small areas of extremely fine grain structure can be distinguished in B.

Magnification: 110 Etched: Dilute Keller's (9A), Molybdic Acid (9B).

A



B

Figure 10. Porosity-containing FS488 bulkhead sample showing the limited anisotropy, although the material appears to consist of two distinct areas containing either large grains or small grains. Large precipitates are associated with the larger grains while smaller precipitates are more evenly distributed. The network of larger grains along with the placement of the larger precipitates would appear to be associated with the grain structure that existed prior to recrystallization, i.e. these regions and features appear to outline the grain boundaries of the structure prior to the solution heat-treatment and ageing cycles.

Magnification: 110 Etched: Dilute Keller's (10A), Molybdic Acid (10B).

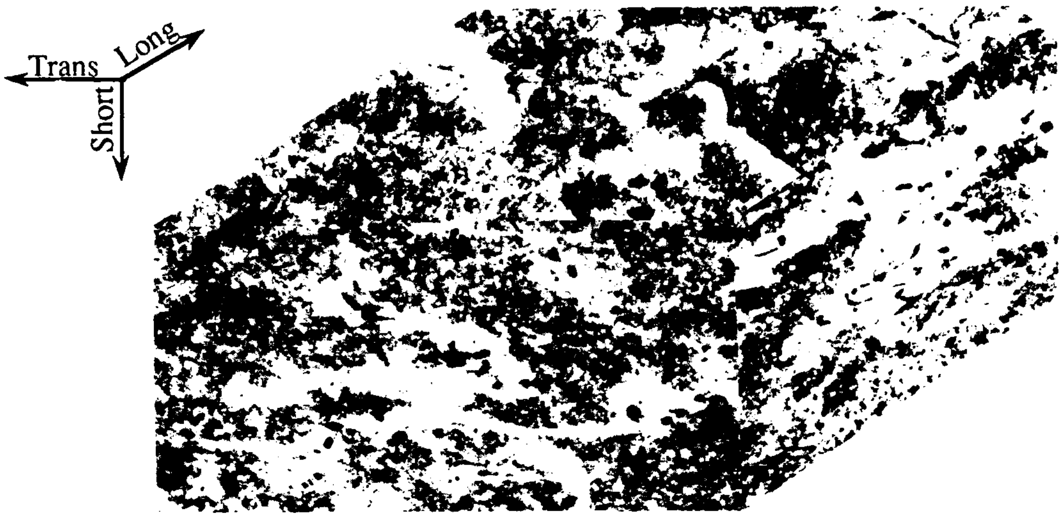


Figure 11. F/A-18 FT40 in flange region of plate has a structure similar to that of the previous sample. The main difference appears to be in the size and number of the large precipitates that are mainly centred in the regions of the large grains. These precipitates appear to be both more numerous and generally slightly larger than those of the previous sample.

Magnification: 110 Etched: Molybdic Acid.

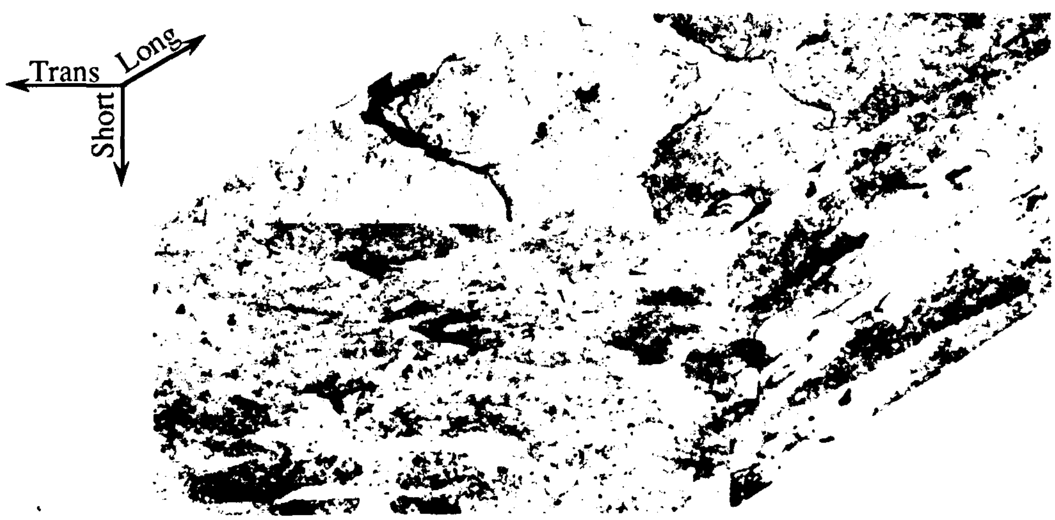


Figure 12. Sections of the F/A-18 FT40 FS 488 bulkhead taken from the centre region of plate showing a fairly anisotropic structure, although the material consists of two distinct regions; large grains outlining the prior grain structure, and small grains clustered within the large grain network. Massive precipitates are associated with the larger grains while smaller precipitates are more evenly distributed.

Magnification: 110 Etched: Molybdic Acid.

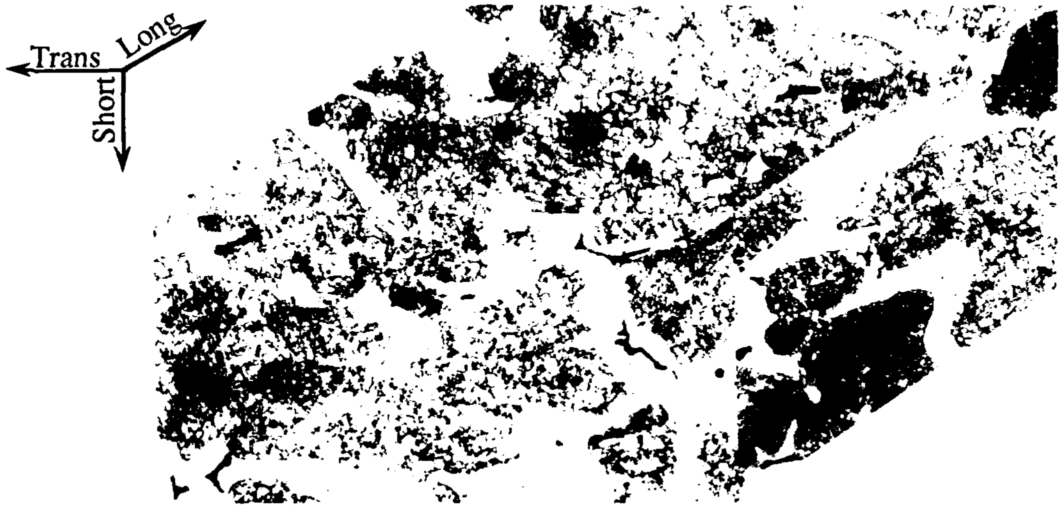


Figure 13. Sections taken from the F/A-18 FT41 FS 488 bulkhead centre plate region showing little evidence of working. The material consists of two distinct regions; large grains outlining the prior grain structure, and small grains clustered within the large grain network. Massive precipitates are associated with the larger grains while smaller precipitates are more evenly distributed.

Magnification: 110 Etched: Molybdic Acid.

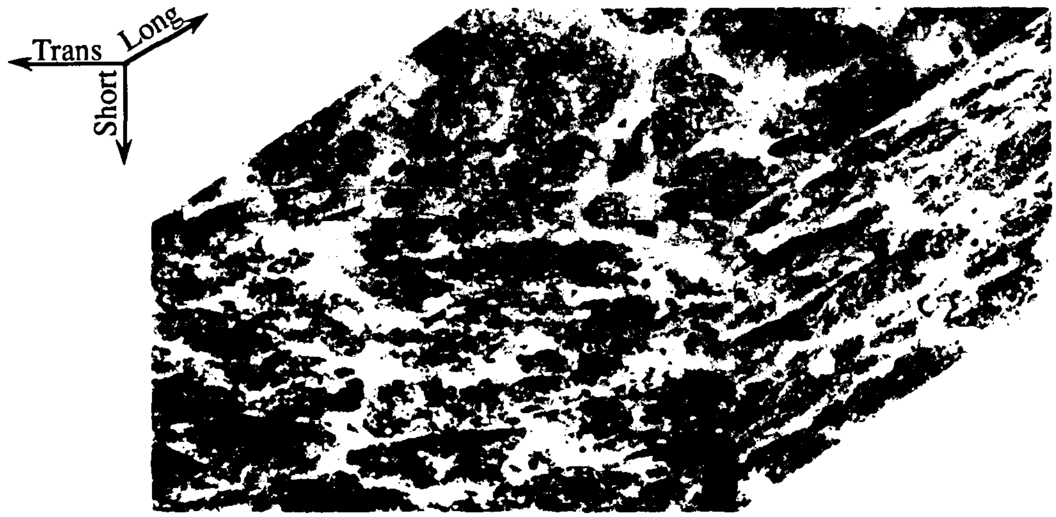
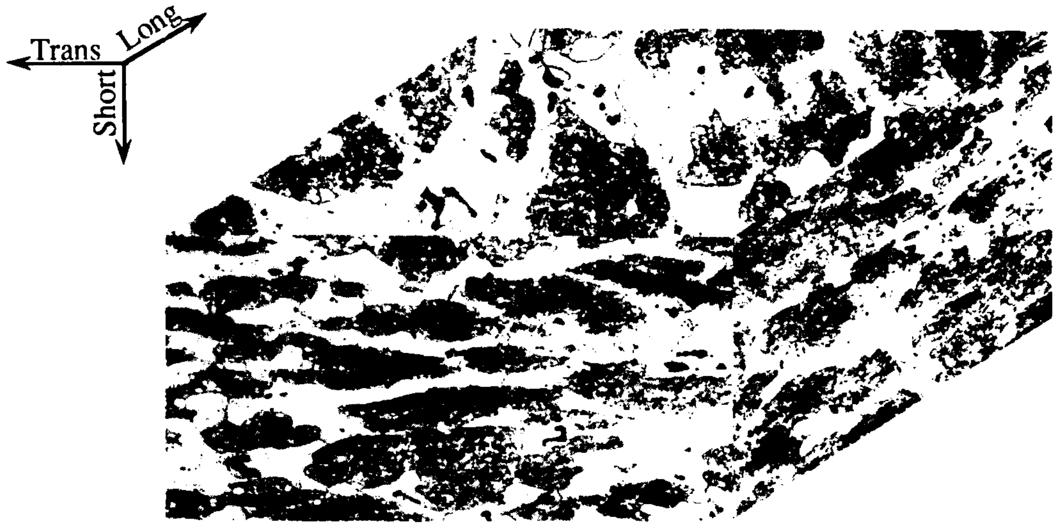
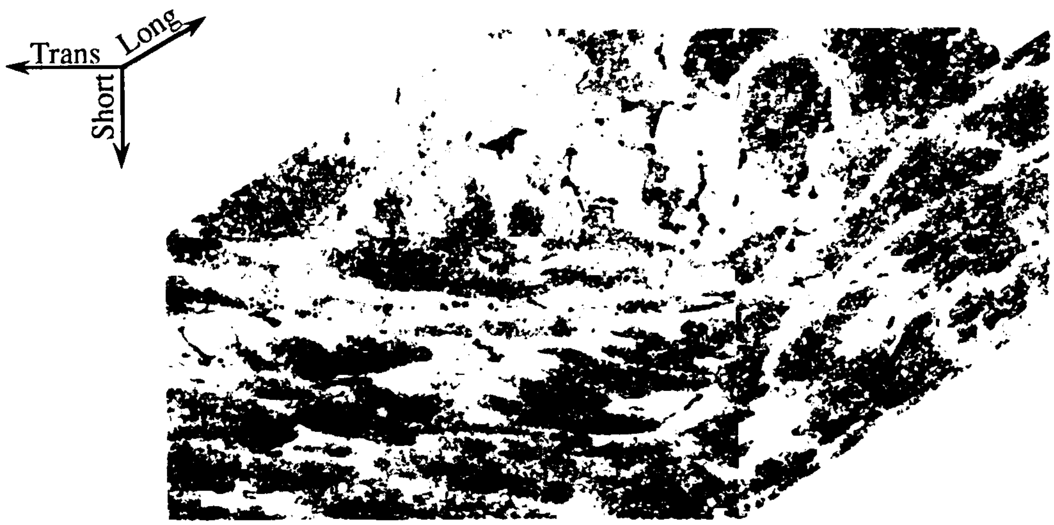


Figure 14. F/A-18 FT40R in flange region of plate, displaying a structure very similar to that in Figure 10

Magnification: 110 Etched: Molybdic Acid.



A



B

Figure 15. Material from the FS488 bulkhead fatigue-tested in Aircraft Structures Division. These micrographs show the limited anisotropy, with two distinct grain sizes. Large precipitates are associated with the larger grains while smaller precipitates are more evenly distributed. The network of larger grains along with the placement of the larger precipitates would appear to be associated with the grain structure that existed prior to recrystallization, i.e. these regions and features appear to outline the grain boundaries of the structure prior to the solution heat-treatment and ageing cycles.

Magnification: 110 Etched: Dilute Keller's (10A), Molybdic Acid (10B).

A

B

Figure 16. Micrographs of the 150 mm (six-inch) plate acquired by Aircraft Structures Division ARL for fatigue test specimens in late 1989. The microstructure of this material is far more isotropic than any of the 150mm thick material examined previously. This structure appears to be closer to the ideal, with a fairly even grain size, although these grains appear to be slightly larger than the fine grains observed in other samples of 150mm plate (c.f. Figures 10 to 15); large precipitates are still present although they are generally of a smaller size.

Magnification: 110 Etched: Dilute Keller's (16A), Molybdic Acid (16B).

Analytical Transmission Electron Microscopy (ATEM) Examination of a Thick Plate Sample

To further increase the understanding of the microstructure of the thick plate material, ATEM was used to examine the submicroscopic ($<1\mu m$) and larger precipitates in one of the thick section 7050 alloy samples (F/A-18 488 Bulkhead FT41). The size and orientation of these precipitates were examined, and the precipitate chemistry was compared with the theoretical composition of precipitates known to occur in this material.

Specimen discs 3mm in diameter were punched from a sample of the bulk aluminium alloy 7050 and mechanically thinned to a thickness of $50\mu m$ using wet and dry emery paper. Thin foils suitable for ATEM work were prepared from these discs by electropolishing in an electrolyte solution of nitric acid and methanol.

Imaging and Energy Dispersive X-ray Spectrometry (EDS) were performed on several specimens using a JEOL 2000FX scanning transmission electron microscope (STEM) fitted with a Tracor Northern TN5500 EDS system. Images were recorded on film using the bright-field mode and spectra were collected over 100 seconds from different sized grains and grain boundary precipitates.

Grain sizes varied from small ($\leq 5\mu m$) to large ($>5\mu m$). The size and orientation of the precipitate particles on the various grain boundaries and the width of the Precipitate Free Zones (PFZ) were measured directly from the images. The average from ten measurements of each type of boundary are summarized in Table 3 for comparison.

All the EDS spectra collected were analysed to give semi-quantitative chemical information from the various grains and precipitates. All the grains were found to be chemically consistent with the nominal composition of the alloy 7050. Various precipitates which had previously been observed by optical methods were analyzed (the compositions of the associated surrounding grains were used as a standard of comparison, thus allowing the differences in spectra to indicate the main elemental composition of the precipitates in a qualitative manner). A summary of the chemical nature of the different precipitates is shown in Table 3.

Table 3

Summary of TEM Results

Shown in Figure	Grain boundary Type	Length (nm)	Width (nm)	PFZ(nm)	Composition.	Orientation (degrees from grain boundary alignment).
17	L-L	≈800	≈100	20-50	Mg, Si & Cu	≈0
17	L-L	<1000	≈100	Not a grain boundary precipitate	Fe & Cu	≈90
18	S-S	30-70	10-40	20-60	Mg & Zn	≈45
19	S-L	280-300	20-40	40-60	Mg, Cu & Zn	≈0
20	S-S	60-100	10-20	70-100	Mg, Si, Cu & Zn	≈45
21	S-S	100-150	30-50	70-100	Mg & Zn	≈20

L-L=grain boundary between large grains
S-S=grain boundary between small grains
S-L=grain boundary between small and large grain

From this table of results it can be seen that all the precipitates lying on the grain boundaries are rich in Mg. The three large precipitates shown in Figure 17 are rich in Fe and Cu and were probably formed during ingot solidification and homogenization and are most likely Al_7Cu_2Fe. These precipitates would have been located at the grain boundaries formed during solidification and appear to have acted as nucleation centres during recrystallization which occurred during working of the alloy. The smaller precipitates (<150nm in length and <50nm wide) occur at the grain boundaries between small grains and tend to lie across the boundaries, with either end penetrating the grains; this presents the appearance of stitching across the grain boundaries (Figures 20 &21). These precipitates were commonly rich in Mg and Zn and are most likely $MgZn_2$ precipitates whose alignment has been strongly influenced by common grain crystallographic directions. The larger precipitates occur on grain boundaries between large grains or between large and small grains. These precipitates most commonly lie along the grain boundaries, are rich in Cu, and are considered likely to be Al_2CuMg. Their larger size appears to have reduced dependence on the orientation of neighbouring grains since the precipitates were orientated along the grain boundaries. Precipitate-free zones have been observed along all the grain boundaries. The width of these regions is generally less than 100nm. The PFZ width between the smaller grains is generally greater than that between the larger grains although the PFZ between the tips of the precipitates and the grains is smaller (Figure 20), and the PFZ appears to narrow towards the centre of the grain boundary, between the precipitates.

Figure 17. The grain boundary between two large grains showing the very large precipitates running at 90° to the grain boundary (one of these is marked V) and the smaller, but still relatively large precipitates along the grain boundary (arrowed).

Magnification: 16000

Figure 18. The grain boundary between two small grains showing small precipitates running at approximately 45° to the grain boundary (one of these is arrowed). Note the difference in size and orientation of the precipitates compared to those in Figure 15.

Magnification: 42500.

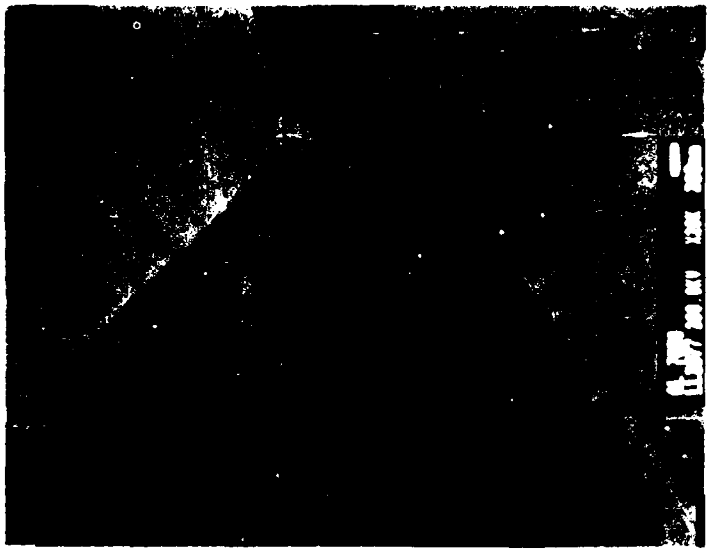


Figure 19. The grain boundary between a small grain and a large grain showing large precipitates running along the grain boundary, or at a shallow angle to the boundary (one of these is arrowed).

Magnification: 22500.

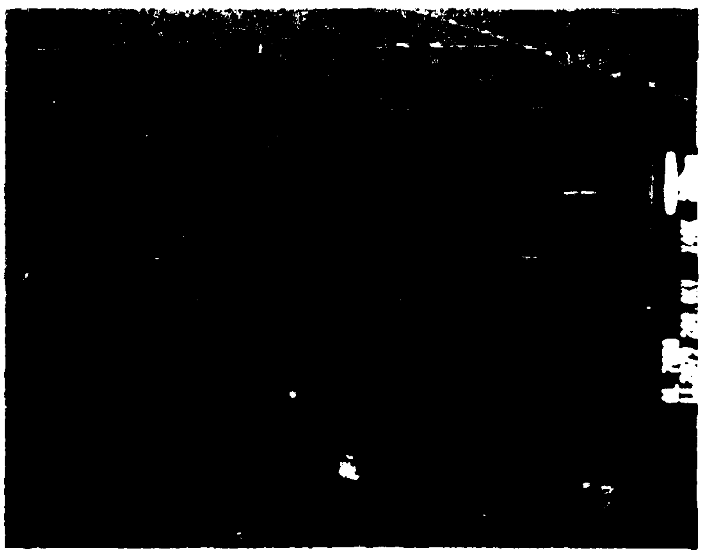


Figure 20. Another grain boundary between two small grains showing small precipitates running at approximately 45° to the grain boundary (one of these is arrowed). Note the broad PFZ that exists at this boundary, which is bridged by the precipitates, which prevent a continuous straight PFZ from forming at these boundaries.

Magnification: 42500.

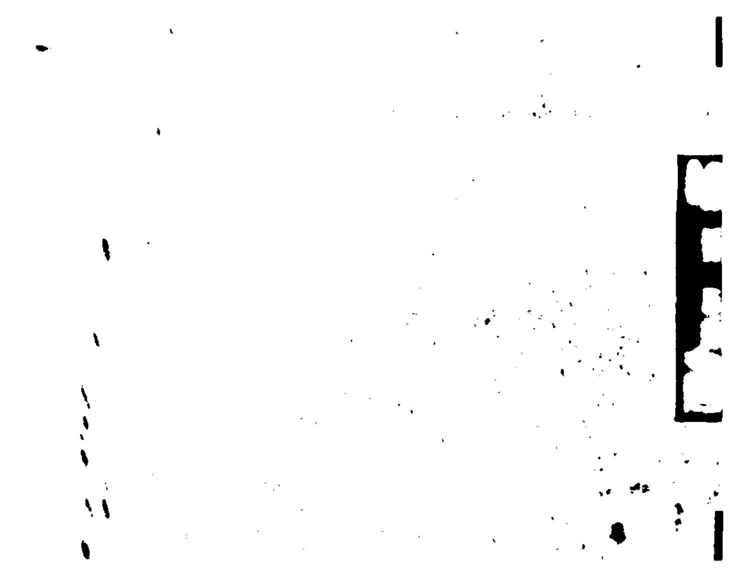


Figure 21. A grain boundary between two small grains showing the same effect as observed in Figure 18.

Magnification: 27500.

DISCUSSION AND CONCLUSIONS

The examinations carried out on these samples of alloy 7050 have revealed a number of interesting features and feature variations. From these observations the following is concluded:

1. The specimens depicted in Figures 3-9 and 16 have microstructures which would be expected in a wrought 7XXX alloy with sufficient working to give even distribution of the Al_7Cu_2Fe, Al_2CuMg and Mg_2Si precipitates, along with a fine uniform grain size. The 150 mm (six-inch) plate acquired by Aircraft Structures Division ARL for fatigue test specimens in late 1989 (depicted in Figure 16) also had a fine uniform grain size, although relatively large precipitates similar to the structures found in the forged specimens (Figures 4-7) were noted.
2. In general the thick-section material examined from the F/A-18 fatigue test specimens appears to be under-worked (the exception being the 150 mm (six-inch) plate acquired by Aircraft Structures Division ARL for fatigue test specimens in late 1989). The precipitates, which should consist of small blocky remnants of Al_7Cu_2Fe, Al_2CuMg and Mg_2Si evenly distributed throughout the matrix, are instead massive elongated and 'Y' shaped particles. The position of these particles appears to outline sections of interdendritic grain boundary structure which originally formed

during solidification of the ingot. Further, grain boundary films were observed in several sections of the thick material. Boundary films and massive elongated and 'Y' shaped particles are considered most undesirable in a material that is required to withstand a high-stress fatigue environment.

3 The large grains observed in the structure of the thick section material examined from the F/A-18 fatigue test specimens were considerably larger than the fine recrystallized grain structure (the exception being the 150 mm (six-inch) plate acquired by Aircraft Structures Division ARL for fatigue test specimens in late 1989), with the large grains being approximately 10 times the diameter of the finer grains. This network of large grains also appeared to follow the interdendritic grain boundary structure which originally formed during solidification of the ingot and it was common to find the large inclusions centred in these large grain networks.

4 TEM examination of one of the 150 mm specimens (FT41, Figure 13) revealed that the orientation and size of the grain boundary precipitates appeared to vary according to the type of grain boundary at which they occurred. This variation has resulted in a more tortuous path for the PFZ in the small-to-small grain boundaries due to the orientation of the precipitates at these boundaries. It is likely that this would result in a difference in the fatigue and corrosion resistance between the types of grain boundaries. The difference would probably result in the small-to-small boundaries having a higher resistance to fatigue and corrosion than the large-to-large and the large-to-small grain boundaries. Evidence to support this hypothesis has been supported in initial work (as yet unpublished).

REFERENCES

[1] Mayer L. W. "Alcoa Green Letter: Alcoa Alloy 7050" Aluminium Company of America, Application Engineering Division, New Kensington, Pennsylvania. (1973) pp3-5.

[2] Anon. Kaiser Aluminum & Chemical Corporation Metallography data sheets 7050.0-7050.71.

[3] Metals Handbook (Ninth Edition), Volume 4-Heat Treatment, American Society for Metals, Metals Park, Ohio, (1981) pp675-718.

APPENDIX

REGION OF SAMPLING

Approximate positions in the original plate from which the samples were taken.

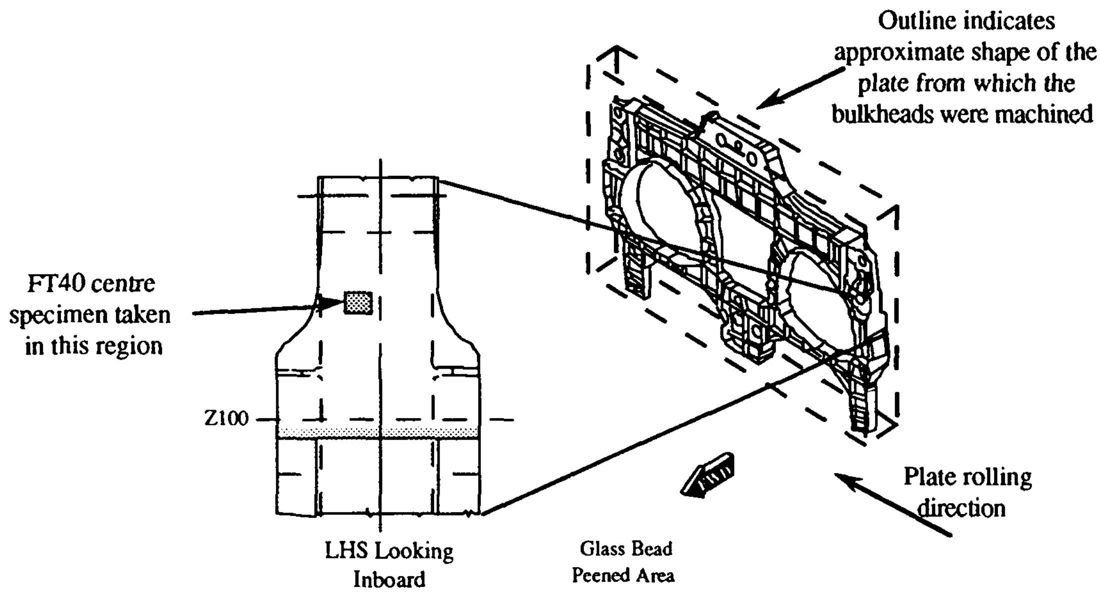


Figure 1 FT40 centre specimen. Not to scale

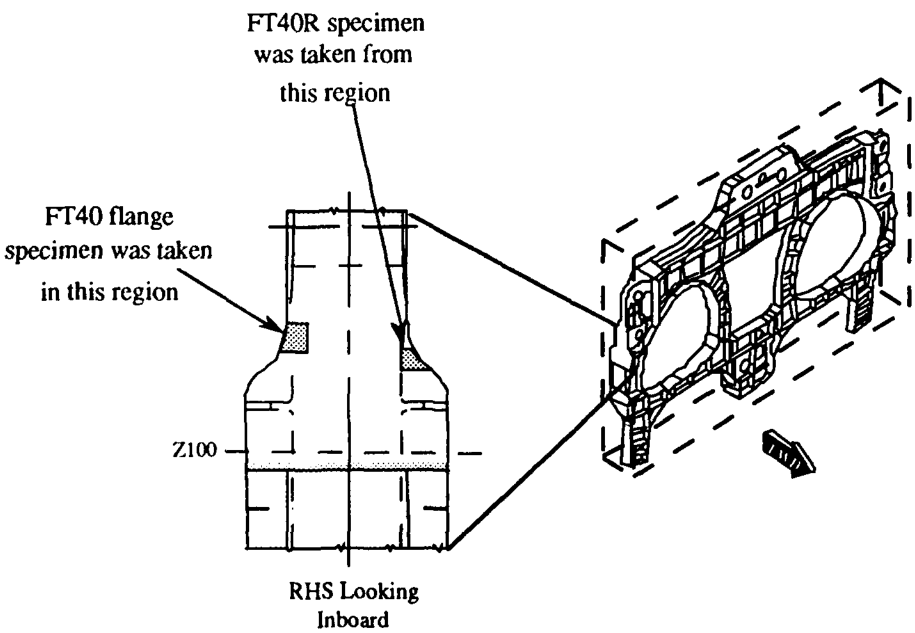


Figure 2 FT40 flange specimen and FT40R specimen. Not to scale

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AR-006-113	ARL-MAT-TM-403	AUGUST 1990	AIR 89/062

4. TITLE	5. SECURITY CLASSIFICATION (PLACE APPROPRIATE CLASSIFICATION IN BOX(S) IE. SECRET (S), CONF. (C) RESTRICTED (R), UNCLASSIFIED (U)).	6. NO. PAGES
EXAMINATION OF THE MICROSTRUCTURE OF 7050 ALUMINIUM ALLOY SAMPLES	U DOCUMENT, U TITLE, U ABSTRACT	24
		7. NO. REFS. 3

8. AUTHOR(S)	9. DOWNGRADING/DELIMITING INSTRUCTIONS
S.A. BARTER N. ATHINIOTIS L. LAMBRIANIDIS	Not applicable

10. CORPORATE AUTHOR AND ADDRESS	11. OFFICE/POSITION RESPONSIBLE FOR:
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14. DESCRIPTORS	15. DISCAT SUBJECT CATEGORIES
Metallography Aluminum alloys Microstructure	110601

16. ABSTRACT

Aluminium Alloy 7050 is used extensively in the F/A-18 aircraft. This report describes the results of examination of a number of samples of Aluminium Alloy 7050 which were taken from FS 488 bulkhead fatigue test specimens adjacent to the fatigue failures and from thinner material which has been used for fatigue test coupons by ARL and F/A-18 manufacturers.

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16. ABSTRACT (CONT).

17. IMPRINT

AERONAUTICAL RESEARCH LABORATORY, MELBOURNE

18. DOCUMENT SERIES AND NUMBER	19. COST CODE	20. TYPE OF REPORT AND PERIOD COVERED
Aircraft Materials Technical Memorandum 403	31 3195	

21. COMPUTER PROGRAMS USED

22. ESTABLISHMENT FILE REF.(S)

23. ADDITIONAL INFORMATION (AS REQUIRED)